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REVEGETATION OF AN ALPINE MINE DISTURBANCE: BEARTOOTH PLATEAU, MONTANA

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ABSTRACT

The first-year results of revegetation research on an alpine mine disturbance on the Beartooth Plateau in Montana are discussed. Plant densities were highest on plots treated with topsoil and fertilizer. Native seed mixtures produced higher plant densities than did introduced seed mixtures on both topsoil and raw spoil plots. Transplanting of native plants was also studied as an alternative revegetation technique. All transplants survived after 1 year, suggesting that this method offers an excellent opportunity for plant establishment on alpine disturbances.

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KEYWORDS: revegetation; alpine; mine rehabilitation; Beartooth Plateau, Montana; transplants

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The impacts of mineral development and of recreational uses are increasing on alpine ecosystems in the western United States. Such activities threaten to disrupt these fragile ecosystems and are already causing serious deterioration of esthetic, watershed, and wildlife habitat values in some areas. The fact that alpine tundra constitutes a relatively small proportion of the total land area in the West is in no way proportional to the importance of the impacts that disturbances have on alpine lands. Alpine ecosystems are of vital importance as metropolitan and agricultural watersheds. In addition, they contain economically valuable mineral resources, and offer popular year-round recreational experiences. These attributes dictate that research on the rehabilitation of alpine disturbances be expanded.

Although considerable research has been directed toward the study of alpine ecosystems (Osburn and Wright 1968; Ives and Barry 1974; Billings and Mooney 1968; Billings 1974; Bliss 1962; Johnson 1969; Mooney and Billings 1961), little work has been devoted to the rehabilitation of alpine disturbances.

Harrington (1946) summarized the performances of a number of plant species that were seeded and transplanted on road disturbances in Rocky Mountain National Park in Colorado. He found that both seeding and transplanting native species were successful in initiating the natural succession of vegetation.

Brink (1964) discussed various factors affecting plant establishment in alpine and subalpine regions of British Columbia. Frost action, amount of snow cover, and drought were found to be limiting factors in these environments. Willard and Marr (1970, 1971) described the rates of vegetation recovery on alpine tundra disturbed by human activities; they speculated that hundreds of years may be required to rebuild the natural ecosystem in alpine environments following severe disturbance. Belsky (1975) studied the effects of an oil spill in an alpine environment near Mt. Baker, Washington. Revegetation with cuttings of heather was more successful after 2 years than seeding with native seeds. Berg and others (1974) described many of the problems associated with the revegetation of alpine disturbances.

A wide variety of disruptive mining practices can be documented within the alpine ecosystem on the Beartooth Plateau. The history of mineral exploration and development in these mountains dates from near the turn of the century. Current widespread exploration for copper, chromium, platinum, and other minerals will likely result in full-scale mining operations in the near future.

The McLaren Mine located near Cooke City, Montana (fig. 1) is an example of the severe impacts resulting from mining in this area. This shallow open-pit mine was operated for the extraction of copper, silver, and gold, and has been essentially abandoned since the early 1950's except for sporadic exploration. In addition to adverse visual impacts, soil erosion and sedimentation are occurring as a result of the near total lack of a vegetative cover and the oxidation of heavy concentrations of pyritic materials is causing severe off-site water quality problems. Acid drainage is continuing to kill the native vegetation adjacent to the mine and has already resulted in the complete destruction of the aquatic ecosystem in the upper Stillwater River. This mine represents an excellent opportunity to study the effects of revegetation on a wide variety of problems related to alpine disturbances. This paper discusses the first-year results of our revegetation research on the McLaren Mine.

STUDY AREA

The geology of the Beartooth Plateau is characterized by an uplifted Precambrian granitic mass from which extensive sedimentary materials have been eroded (Bevan 1923; Loverling 1929). Basalt and acid porphyry intrusions and some limestone outcrops are evident. Most of the highly mineralized zones lie on the flanks of the main Beartooth uplift, as is exemplified by the Stillwater complex on the north and the Cooke City

Figure 1.--The McLaren Mine is located on the Beartooth Plateau near Cooke City, Montana.

Mining District on the southwest. The shallow and weakly developed soils, typical of alpine environments are coarse textured and rocky on the drier areas (Nimlos and others 1965). The dominant climatic features include short growing seasons of 60 to 70 days with cool summer temperatures and high solar radiation loads (Johnston and others 1975). Annual precipitation is estimated to range between 1,140 and 1,525 mm (45 and 60 in), most of which occurs as snow during the winter months. The major alpine plant communities on the Beartooth Plateau have been described by Johnson and Billings (1962).

The McLaren Mine is located about 8 km (5 miles) north of Cooke City, Montana, at an elevation of 2,950 m (9,678 ft) on a generally southwest exposure. The main ore body is a highly mineralized, hydrothermal pyritized-copper deposit, with primary values in gold, copper, and silver. The area disturbed is about 12 ha (30 acres). The mine is in an alpine-subalpine transition zone, and many of the plant communities described by Johnson and Billings (1962) are found in this area. The dominant vegetation consists of perennial herbaceous plants, including grasses, sedges, and forbs. Fingers of subalpine fir (*Abies lasiocarpa*) and limber pine (*Pinus flexilis*) intrude into the predominantly herbaceous alpine communities. These trees display the characteristic krummholz nature of treeline environments.

METHODS

The revegetation study was initiated on the McLaren Mine in 1974. Seventy-two subplots, each 2 m^2 (6.56 ft^2) were established on rough-graded mine spoil 30 m^2 (98 ft^2) (fig. 2). Topsoil, consisting of the upper 60 cm (2 ft) of material from relatively undisturbed remnant of native soil within the mine disturbance, was spread over half of the study site to a depth of about 20 cm (8 in). Thus, two main plots were established; each was 15 by 30 m (49 by 98 ft) in size and consisted of 36 subplots.

Selection of plant species used in this study was based on observations of natural plant succession on road disturbances and mine overburden piles. Some native species display an apparent wide adaptability to establishment and growth on a variety of disturbed sites in subalpine and alpine environments. Introduced species were selected on the basis of somewhat more limited experience.

Seed of the native species was collected from areas immediately adjacent to the McLaren Mine (table 1). The seed was cleaned and prepared in the Forestry Sciences

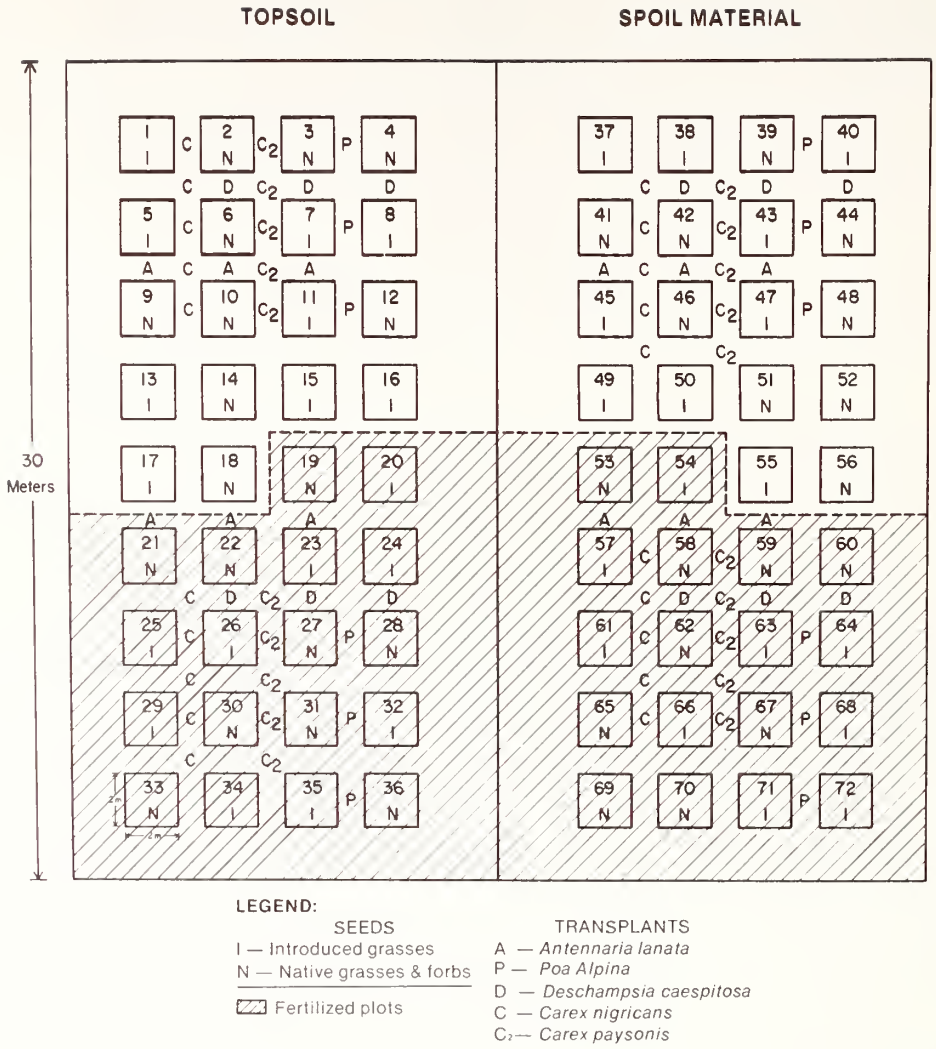

Figure 2.--Location and treatments applied to McLaren Mine revegetation plots.

Laboratory at Logan, Utah, prior to establishment of the plots. Seed of introduced species was purchased from commercial outlets, and insofar as possible, only strains that originated in the Rocky Mountain States were used.

The revegetation treatments applied to each main plot included nine replications each of four randomly located treatments: (a) mixture of seeded native species with fertilizer, (b) mixture of seeded native species without fertilizer, (c) mixture of seeded introduced species with fertilizer, and (d) mixture of seeded introduced species without fertilizer. The fertilizer used is a 16-16-16 granular mixture applied at the equivalent rate of 111 kg N per ha (100 lb N per acre). Plots were broadcast seeded in the fall of 1974 at the rate of 56 kg per ha (50 lb per acre). The percentage of pure-line seed was not determined. The fertilizer was applied after the seed. Then the plots were thoroughly raked and packed.

Table 1.--*Native and introduced species seeded on the McLaren Mine, and the seeding rates used*

Species	Seeding rate	
	kg/ha	*(lb/ac)*
NATIVE		
Tufted hairgrass *(Deschampsia caespitosa)*	17.0	(15.0)
Alpine bluebrass *(Poa alpina)*	14.2	(13.0)
Alpine timothy *(Phleum alpinum)*	14.2	(13.0)
Spike trisetum *(Trisetum spicatum)*	0.6	(0.5)
Slender wheatgrass *(Agropyron trachycaulum*[1]*)*	5.8	(5.0)
Spreading wheatgrass *(Agropryron scribneri)*	0.6	(0.5)
Woolly pussytoes *(Antennaria lanata)*	0.6	(0.5)
Mountain dryad *(Dryas octopetala)*	0.6	(0.5)
Sedge *(Carex paysonis)*	2.4	(2.0)
	56.0	(50.0)
INTRODUCED		
Meadow foxtail *(Alopecurus pratensis)*	17.0	(15.0)
Timothy *(Phleum pratense)*	8.5	(8.0)
Smooth brome *(Bromus inermis)*	11.3	(10.0)
Intermediate wheatgrass *(Agropyron intermedium)*	5.6	(5.0)
Slender wheatgrass *(Agropyron trachycaulum*[1]*)*	5.6	(5.0)
Alta fescue *(Festuca arundinacea)*	5.6	(5.0)
Orchardgrass *(Dactylis glomerata)*	2.4	(2.0)
	56.0	(50.0)

[1]Two strains of this species were used: a native strain growing near the site, and a commercially available strain.

At the time the plots were seeded, 76 transplants of native species collected from road cuts near the mine were also established. Whole, dormant plants were transplanted in rows between the subplots (fig. 2). Species transplanted were: Woolly pussytoes (*Antennaria lanata*), sedge (*Carex paysonis*, and *C. nigricans*), tufted hairgrass (*Deschampsia caespitosa*) and alpine bluegrass (*Poa alpina*).

In September 1975, 1 year after seeding, total plant density was measured on three 10-by 40-cm (3.94 X 15.75 in) quadrats systematically placed in each subplot. Depth of root penetration was observed for several plants under each treatment. Each subplot was photographed from a height of 2 m (6.1 ft); these photographs were used to determine plant cover with a dot-grid overlay. Transplant survival was determined on the basis of presence or absence of living tissue on the original plant.

Microenvironmental characteristics on the study site were monitored throughout the 1975 growing season. Factors monitored were: solar radiation, net radiation, windspeed, relative humidity, air temperature, soil-surface temperature, and soil-temperature and soil-water potential at various depths. These data were recorded at 2-hour intervals using a battery-powered, data logger system. We measured precipitation with a recording intensity rain gage.

RESULTS AND DISCUSSION

First-year results from the revegetation plots are summarized in table 2. The density of native species was significantly higher ($\alpha = 0.01$) than introduced species under all treatments. Plant densities were generally higher on fertilized plots under all treatments, illustrating the importance of fertilizer applications to first-year success of revegetation efforts. However, introduced species on the topsoil plot showed no appreciable differences between the effects of treatments with and without fertilizer. Native species were more responsive to fertilizer than introduced species on both soils.

Plants growing on fertilized plots were taller and had deeper root penetration than the same species on unfertilized plots. Deeper root penetration apparently increases seedling survival during periods of midsummer drought. Microenvironmental data collected at the McLaren Mine site indicate extended periods of severe soil water deficiences. For example, soil water potentials of -30 bars were measured in the upper 15 cm (6 in) of soil during early August. Below-freezing soil temperatures were measured, and needle ice formation was observed during the growing season. Deeper root penetration may limit frost heaving of seedlings under these conditions.

Total plant cover was very low after one growing season, even on plots where plant density was highest. It was virtually impossible to make valid estimates of plant cover because the plants were so small, and in some cases, the density so low. The highest cover estimated for any treatment was about 2 percent, which occurred on the topsoil-native-fertilizer treatment. All other treatments had lower percent cover.

All transplants, which included five species, survived and were actively growing after 1 year. The mature plants selected for transplanting had extensive root systems and crown development, and apparently were capable of tolerating greater microenvironmental stress than were seedlings. Germinating seedlings are more sensitive than mature plants to periods of severe desiccation, frost heaving, and other environmental hazards. Therefore, the use of transplants may more nearly insure rapid plant establishment and development on alpine disturbances.

It would be impractical to consider using transplants to establish an immediate, complete cover on any disturbance. A fairly large percentage of the soil surface will remain unprotected from erosion processes until lateral growth of the transplants extends into the open spaces. As yet, little is known about the rate of lateral spread by transplants; so it is difficult to assess the relative advantages of the two revegetation methods (transplanting versus seeding) for establishing a complete ground cover. Also, little research information has been published about the possibility of using various combinations of the two methods.

Some characteristics of the spoils and topsoil before the plants were established are summarized in table 3. These data are presented only to contrast the differences between the spoil and topsoil materials. Unfortunately, few data are available as to the acid and heavy metal tolerances of the species used. Of particular importance are

Table 2.--*First-year results of plant density on the McLaren Mine revegetation plots (average number of plants per m^2)*

Species	Topsoil		Spoil	
	Fertilizer	No fertilizer	Fertilizer	No fertilizer
Introduced	360	401	84	26
Native	1,306	1,044	895	96

Table 3.--*Results of pretreatment analysis of native topsoil and mine spoils materials on revegetation plots*[1]

Planting sites	pH	>2mm	Organic matter	Kjeldahl nitrogen	NO_3-n	Exchangeable K	Ca	Mg	Na	$HClO_4$ digest Fe	Al	Zn	Cu
		percent			*P/M*	*-----meq/100 g-----*				*Percent*		*---P/M---*	
Spoils	3.8	54	0.9	0.06	0.9	0.1	1.6	0.2	0.2	24.5	4.6	108	1,012
Topsoil	5.0	46	2.4	.13	.5	.2	3.6	.4	.2	14.6	2.8	99	975

[1]Analyses were performed by the Utah State University Soil Testing Laboratory and followed methods outlined by Chapman and Pratt (1961).

the low pH, high percent coarse fragments, low nutrient levels, and high concentration of such heavy metals as iron and aluminum. One year after planting, no significant changes in soil characteristics were noted except that the concentrations of N, P, and K were higher on the fertilized plots.

Various soil problems on disturbed areas that may be limiting to revegetation efforts are inherent in alpine environments. These may include low fertility, low cation-exchange capacity, poor water-holding characteristics, and low soil pH and associated heavy metal toxicity. Although native species may be climatically adapted, soil limitations may preclude successful establishment and survival. However, these soil limitations can be at least partially improved by the use of various amendments.

In addition to the limiting characteristics of the mine spoils, certain micro-environmental factors seem to contribute to the poor conditions for plant growth. On the McLaren Mine, midgrowing season drought apparently caused a high mortality of developing seedlings. The average annual precipitation on the McLaren site is at least 1,200 mm (47 in), which occurs mostly as snow. However, during the 1975 growing season (late July through early September) total precipitation was only 14 mm (0.6 in). This together with high solar radiation flux densities (maxima of 1.8 cal cm^{-2} min^{-1}, but averaging 1.3 cal cm^{-2} min^{-1}) and variable high winds (maximum 63 km/h (101 mi/h), but averaging 6.8 km/h (11 mi/h)), contributed to the low soil-water potentials measured on the plots. These data illustrate the relatively severe microclimate conditions on the plots and indicate the high evapotranspiration potentials and high soil water stresses in the plant environment.

CONCLUSIONS

Native species are apparently better adapted for revegetation of alpine disturbances than are introduced species. The native plants are at least climatically adapted and are more capable of surviving periods of environmental stress that may be unique to the area. Fertilizer improves plant growth and survivial of first-year seedlings, and should be incorporated in all revegetation efforts in alpine environments. However, the degree of plant development after one growing season will be minimal at best because of the severe nature of both the climatic and soil environments. Transplants of native species appear to offer a highly successful alternative to seeding. Although our data are only first-year results, they do tend to support these observations. If native species are to be used extensively, however, there is a need to develop nurseries for the large-scale production of plants and seeds.

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